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(54) IMPROVEMENTS IN AND RELATING TO AN AXIAL PISTON MACHINE

(71) We, ROBERT BOSCH G.m.b.H., a German company of, Postfach 50, Stuttgart, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an axial piston machine comprising a rotary cylinder block, having cylinder bores disposed in a circle around a drive shaft and having pistons slidable therein, the openings of said cylinder bores co-operating with two kidney-shaped apertures disposed in a circle in a valve plate, said apertures being separated from each other by a web, each web having a recess formed therein, the recesses being disposed diametrically opposite to each other and being connected to each other through a duct.

An axial piston machine of the kind heretofore described is disclosed in the journal "Olhydraulik und Pneumatik", No. 12, 1968, page 9 *et seq.* The arcuate distance between the end of a kidney-shaped aperture and the adjacent recess in the web — measured on the circle in which the openings of the cylinder bores are disposed — is smaller than the greatest or arcuate width of the opening. Consequently, communication is established between one recess and one kidney-shaped aperture over a defined angle of rotation of the cylinder block. A cylinder bore which changes from the high pressure side to the low pressure side is provided with communication to the low pressure side through the duct, the recess and a cylinder bore which, during this period of time, forms a bridge between the kidney-shaped aperture on the low pressure side and the other recess, namely after communication with the kidney-shaped aperture on the high pressure side is cut off. The pressure medium still contained in the cylinder bore, the so-called dead volume, expands through this communication duct to the low pressure side. The dead volume refers to that volume of pressure medium enclosed by the piston in a longitudinal bore between the piston end face and the oppositely disposed wall after the communication between the cylinder chamber and the high pressure slot or inlet, is cut off just before the piston reaches the upper dead centre position. If a cylinder bore changes from the low pressure side to the high pressure side it communicates in the manner described hereinabove with the kidney-shaped aperture of the high pressure side so that the pressure medium is precompressed in the cylinder bore. Sudden pressure change, compression or relief of the medium in the bore chamber which is closed while the web is traversed, are thus moderated so that stress peaks are reduced and noises are minimized.

This known arrangement however suffers from the disadvantage that on the one hand stored compression energy enclosed in the cylinder bores is lost, while on the other hand pressure medium for precompression of the cylinder bore contents is removed from the high pressure side, a feature leading to efficiency losses and pressure fluctuations.

It is an object of the present invention to provide an axial piston machine of the kind described heretofore, having a higher efficiency and lesser pressure fluctuations in the high pressure and low pressure ducts. According to the invention this is achieved in that the arcuate length of the web, measured on the circle in which the cylinder bores are disposed, is at least equal to twice the arcuate or maximum width of the opening to a cylinder bore plus the width of the recess formed in a web, also measured on the previously mentioned circle.

This measure ensures that cylinder bores which change from the high pressure side to the low pressure side and those which change from the low pressure side to the high pressure side communicate with each

other through the duct only when their communication to the kidney-shaped apertures in the valve plate member is interrupted so that pressure compensation between them takes place. Accordingly, the principal part of the energy stored in the dead volume is gained for precompression of the cylinders which change over to the high pressure side. An improved suction characteristic and noise reduction of the machine is also obtained.

It is particularly advantageous if the duct is or includes an annular groove formed in the inner peripheral wall of the valve plate and closed in a sealing-tight manner by an annular member so as to produce an annular duct.

One embodiment of the axial piston machine in accordance with the invention, will now be described with reference to the accompanying drawings in which:

Figure 1 is a longitudinal section through an axial piston machine according to the invention;

Figure 2 is a cross-section through the cylinder block of the axial piston machine along the line II—II in Figure 1;

Figure 3 is a plan view of the valve plate of the axial piston machine as seen in a section taken along the line III—III in Figure 1;

Figure 4 is a section through the valve plate member along the line IV—IV in Figure 3;

Figures 5*a*—*c* show in diagrammatic form the progress of pressure compensation in an axial piston machine having an odd number of cylinders, and

Figures 6*a*—*c* show in diagrammatic form the progress of pressure compensation in an axial piston machine with an even number of cylinders.

The axial piston machine shown in Figures 1 and 2 comprises a casing 1, closed by a casing cover 2. A drive shaft 3 is journalled in the end 23 of the casing 1 in a roller bearing 4 and in the casing cover 2 in a ball bearing 5 and is positively connected to a cylinder block 6 by means of a spline portion 7 of the shaft 3. Cylinder bores 8, having pistons 9 sliding therein and provided with pivotable sliding shoes 10 bearing on a swashplate 11, are disposed in a circle concentric with the cylinder black 6 and parallel to the drive shaft, said bores traversing through the said cylinder block. The sole of each sliding shoe 10 is provided with a recess 12 which communicates through a restrictor orifice 13 in the sliding shoe and a stepped bore 14 in the piston, with cylinder chamber 15 defined by each cylinder bore 8.

The cylinder bores 8 merge into slot-shaped apertures 16, disposed on a circle having a diameter D and the arcuate length of said apertures, measured along an arc of the aforementioned circle, corresponds approximately to the diameter of the cylinder bores 8.

The cylinder block 6 is provided with an axial bore 17 through which the drive shaft 3 passes. A compression spring 18, disposed on said shaft in the aforementioned bore 17, bears against a shoulder 19 of the splined portion 7 of the drive shaft 3 and thrusts the cylinder block sealingly against a valve plate 21 through a disc 20 which is mounted on the drive shaft and which bears against a retaining ring 38 fitted in a groove in the bore 17, the said valve plate 21 being disposed in a recess 22 in the end 23 of the casing. The valve plate member 21 is provided with two kidney-shaped apertures 24 and 25 (Figure 3) which co-operate with the cylinder bores 8 and are arranged on the aforementioned circle. Two stepped bores 26 and 27 in the end 23 of the casing 1 open into the apertures 24 and 25 and independently of the delivery direction, form the pressure medium inlet and outlet of the machine.

Details of the construction of the valve plate 21 of the axial piston machine illustrated in Figure 1 are shown in Figures 3 and 4. Recesses, in this instance in the form of bores 30, 31 are provided in web portions 28 and 29 respectively and disposed on the circumference of the circle D between the two kidney-shaped apertures 24 and 25 and symmetrically thereto. The diameter of each bore 30, 31 is no greater than the distance between adjacent apertures 16 of the cylinder chamber 15, as measured on the circumference of the said circle. Furthermore, the length of each web 28 and 29 is at least equal to twice the arcuate, or largest, width of the opening to a cylinder bore 8 plus the width of one of the recesses 30 or 31 formed in a web.

The two bores 30 and 31 communicate with an annular groove 34 through separate radial ducts 33, sealingly closed relative to the exterior by means of a screw or pin 32, the said annular groove 34 extending in the wall of a central bore 35 of the valve plate member 21. A ring 36, disposed in sealing-tight manner in the central bore, covers the annular groove 34 to produce a closed duct 37 (Figure 4) which communicates with both bores.

When the cylinder block 6 is rotated, for example in the clockwise sense, pressure medium is sucked through the bore 26 and the passage 24 in the valve plate by a piston which is moving away from the valve plate and is forced through the passage 25 in the valve plate and the bore 27 into a delivery pipe line (not shown) by a piston which is moving towards the valve plate.

The particular cylinder bores 8, which

cover the bores 30 and 31 in the webs of the valve plate, are thus joined to each other by the duct 37 so that pressure compensation takes place between the aforementioned cylinder bores.

The stepped progress of pressure compensation for an axial piston machine having an odd number of cylinders is illustrated in Figures 5*a*, 5*b* and 5*c*.

The cylinder bores which accommodate the pistons are designated 8*a*, 8*b*, 8*c* and so on.

During rotation in the clockwise direction of the cylinder block the cylinder bore 8*a* in position A and the cylinder bore 8*b* in position C change from communication with the aperture 24 on the low pressure or suction side to communication with the aperture 25 on the high pressure side, and the cylinder bore 8*f* in position B changes from the high pressure to the low pressure side. In the Figure 5*a* position communication between the cylinder bores 8*b*, 8*f* through the bores 30 and 31 and the duct 37 has just been interrupted and pressure compensation has already taken place between the two cylinder bores 8*b* and 8*f*. In the course of further rotation of the cylinder block the cylinder bore 8*a* covers the bore 30 whilst the cylinder bore 8*f* still covers the bore 31 so that the last-mentioned cylinder bores will then be in communication. Pressure compensation takes place during which the pressure in the cylinder bore 8*a* increases. When the cylinder bore 8*a* reaches position B and the cylinder bore 8*f* reaches position C^1 this process will have been completed. The pressure in the cylinder bore 8*f* has a minimum value prior to its entry into communication with the low pressure side. In the course of further rotation of the cylinder block the cylinder bore 8*e* which has just moved out of communication with the aperture 25, on the high pressure side and in which the full discharge pressure still prevails, covers the bore 31 while the cylinder bore 8*a* continues to cover the bore 30. Pressure compensation between these two cylinder bores is then effected through the duct 37, the pressure in the cylinder bore 8*a* continuing to increase. After the cylinder bore 8*a* has reached position C, and cylinder bore 8*e* has reached position B^1 the pressure compensation and accordingly precompression of the cylinder bore 8*a* will have been completed. Pressure compensation between the cylinder bores which leave the high pressure side of the machine and those which change from the low pressure side to the high pressure side therefore takes place in two stages. It is therefore possible to utilise, to a maximum extent, the pressure energy stored in the dead volume of medium. At the maximum pivot angle of the swashplate 11, the total efficiency of the pump is increased by approximately 1% and the percentage improvement of efficiency is substantially higher at smaller pivot angles.

In addition to improving the efficiency the lower pressure differences between the cylinders entering the high pressure or low pressure zones respectively, and those zones results in a substantial reduction in the pressure fluctuations in the high pressure and low pressure ducts.

The pressure compensation characteristics in an axial piston machine having an even number of cylinders is illustrated in Figures 6*a* to 6*c*.

During rotation in the clockwise direction the cylinder bore $8a^1$ in position A and the cylinder bore $8b^1$ in position C change from communicating with the aperture 24, on the low pressure side, to communicating with the aperture 25, on the high pressure side, the cylinder bore $8f^1$ in position A^1 and the cylinder bore $8g^1$ in position C^1 change from communicating with the high pressure side to communicating with the low pressure side.

In the course of further rotation of the cylinder block the end of the cylinder bore $8a^1$ will cover the bore 30 and the end of the cylinder bore $8f^1$ will cover the bore 31 so that pressure compensation may then take place between the aforementioned cylinder bores through the duct 37.

When the cylinder bores $8a^1$ and $8f^1$ respectively reach the position C and C^1, communication between them will once again be interrupted and the pressure compensation is completed. Pressure in the cylinder $8f^1$ will diminish more rapidly than the pressure in the cylinder $8a^1$ increases, since the volume (of medium) then enclosed in said cylinder is greater than the volume of the cylinder bore $8f^1$ by a volume corresponding to a displacement stroke of a piston.

By contrast to machines with an odd number of cylinders in which pressure compensation takes place in two stages, pressure compensation is performed in one stage with an even number of cylinders, that is to say only between oppositely disposed cylinders. The energy recovery in this case is somewhat less; however, since owing to the reduced pulsation involved, machines having an odd number of cylinders are commonly used at present, a machine provided with an even number of cylinders is of only slight importance.

WHAT WE CLAIM IS:—

1. An axial piston machine comprising a rotary cylinder block having cylinder bores disposed in a circle around a drive

shaft and having pistons slidable therein, the openings of said cylinder bores co-operating with two kidney-shaped apertures disposed in a circle in a valve plate, said apertures being separated from each other by a web, each web having a recess formed therein, the recesses being disposed diametrically opposite to each other and being connected to each other through a duct or ducts, characterised in that the arcuate length of the web as measured on the said circle is at least equal to twice the largest or arcuate width of the opening to a cylinder bore plus the width of the recess formed in a web, also measured on the aforementioned circle.

2. An axial piston machine according to claim 1, characterised in that the recesses are connected to each other through an annular groove formed in the inner peripheral wall of the valve plate, the said groove being closed in a sealing-tight manner by an annular member so as to produce an annular duct.

3. An axial piston machine according to claim 1 or claim 2, characterised in that each recess is a bore extending into a duct through which the said bores are connected together.

4. An axial piston machine substantially as herein described with reference to Figures 1 to 4, Figures 1 to 4 and Figures 5*a* to 5*c* or Figures 1 to 4 and Figures 6*a* to 6*c* of the accompanying drawings.

A. A. THORNTON & CO.,
Chartered Patent Agents,
Northumberland House,
303/306 High Holborn,
London, W.C.1.

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1324756 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig.1

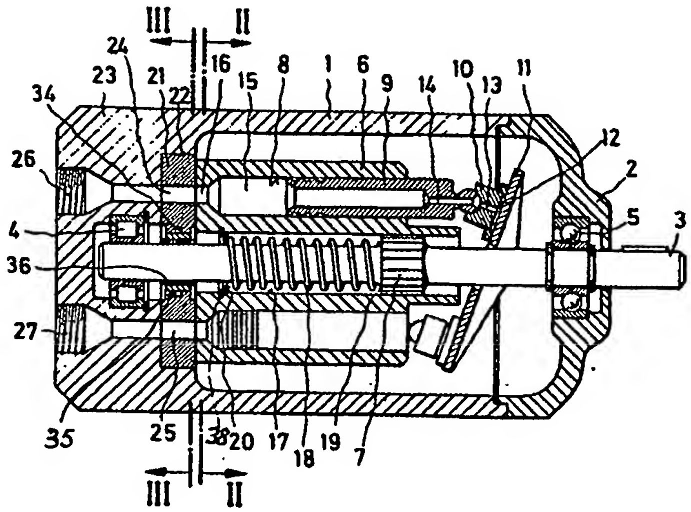
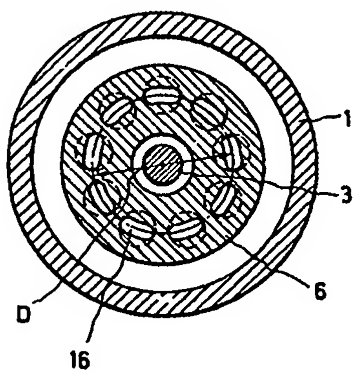


Fig.2



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3 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 2

Fig.3

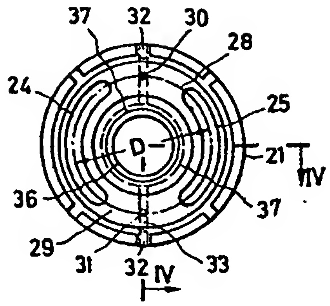


Fig.4

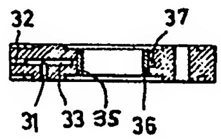


Fig.5a

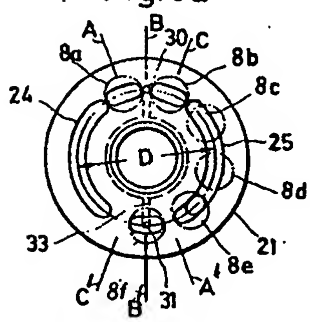
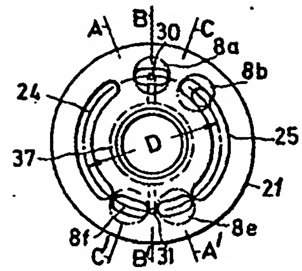


Fig.5b



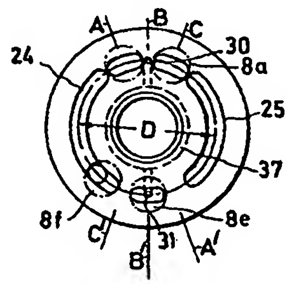


Fig.5c

Fig.6a

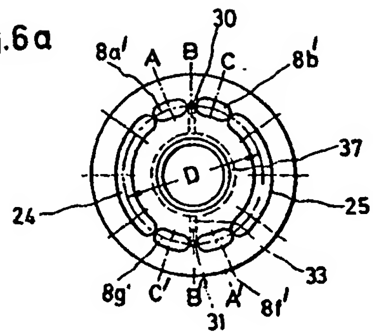


Fig.6b

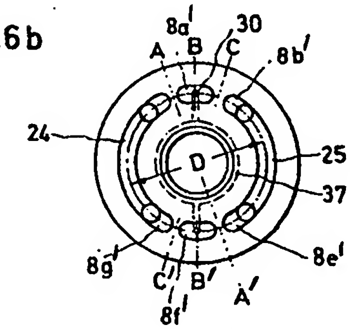


Fig.6c